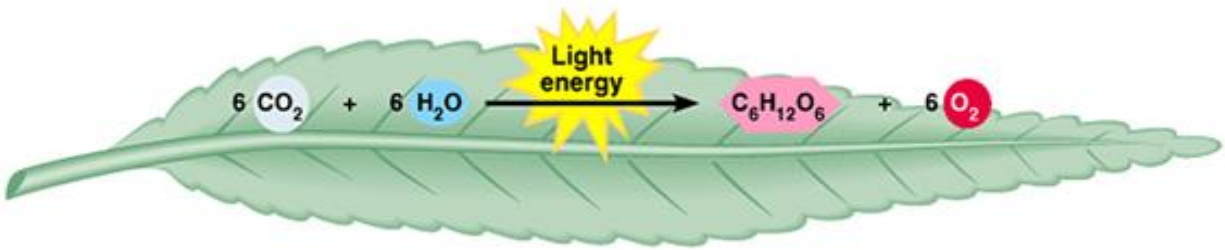
CARBOHYDRATES-Introduction

Carbohydrates occur abundantly in nature i.e. in plants and animals.

In plants: (Photosynthesis)



The synthesized glucose is stored in the form of starch and used to synthesize cellulose of the plant framework.

In animals: The metabolic synthesized glucose is stored in the form of glycogen, serves as an important source of energy for vital activities.

Definition:

Carbohydrates are polyhydroxy aldehyes or polyhydroxy ketones, primarily composed of carbon, hydrogen and oxygen. These are the **hydrates of carbon.**

Carbohydrates are also known as **Saccharides** (Sakcharon means Sugar, Greek) having general formula $\mathbf{C_n(H_2O)_n}$ where n≤3.

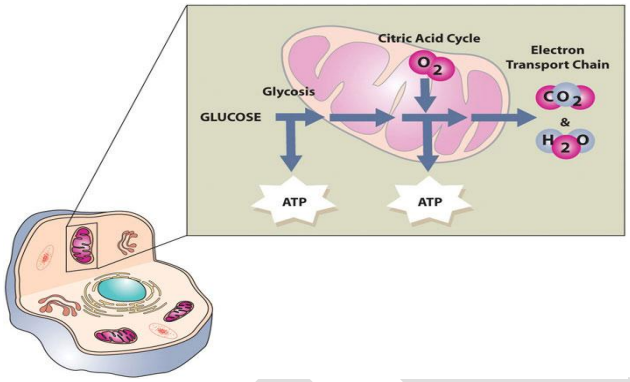
Ex: Glucose - $C_6(H_2O)_6$ or $C_6H_{12}O_6$

Exceptions:

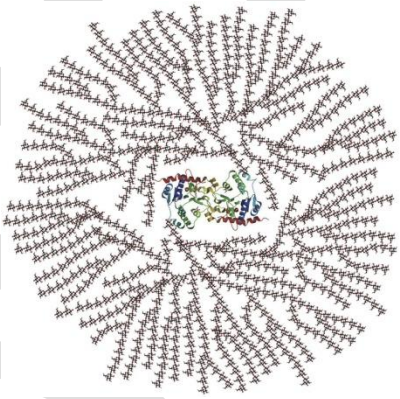
1. Acetic acid $C_2H_4O_2$ and Lactic acid $C_3H_6O_3$ appear as hydrates of carbon, but these are non carbohydrates.
2. Rhamnohexose $C_6H_{12}O_5$ and deoxyribose $C_5H_{10}O_4$ doesn't satisfy general formula, but they are carbohydrates. Hence all carbohydrates are not hydrates of carbon.

Functions of carbohydrates:

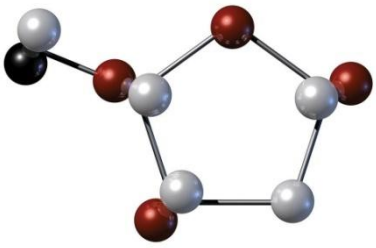
- They are the most abundant dietary source of energy (4Cal/g) for all organisms.

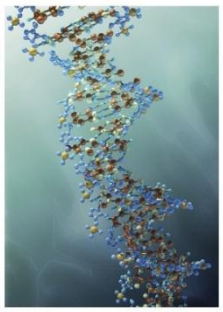


- Carbohydrates serve as the storage form of energy (glycogen) to meet the immediate energy demands of the body.



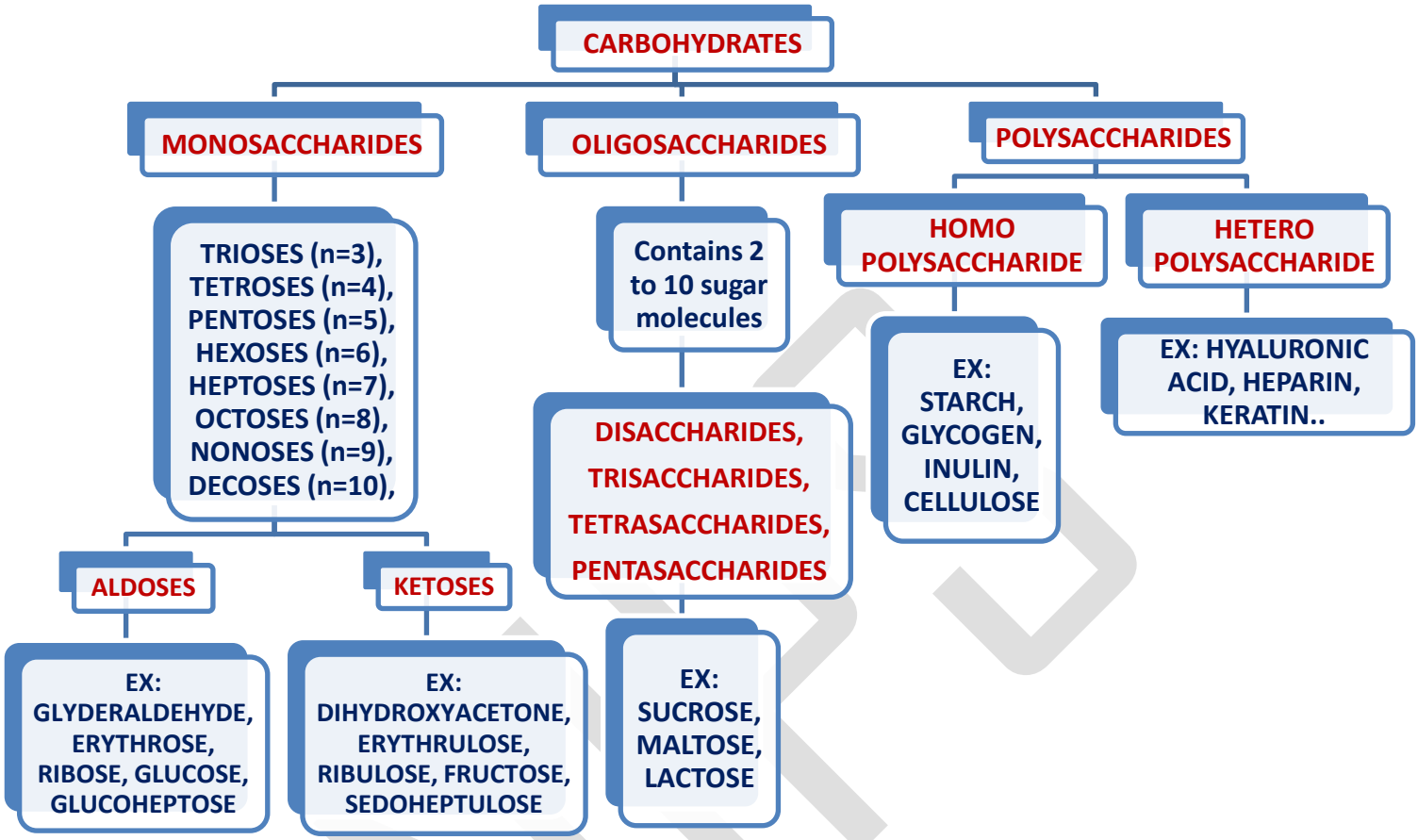
- Carbohydrates are essential building blocks of important macro molecules such as RNA, DNA & ATP.





- Carbohydrates participate in the structure of cell membrane and cellular functions such as cell growth, adhesion and fertilization.
- Carbohydrates help in metabolism of lipids or fats.

Classification of Carbohydrates:

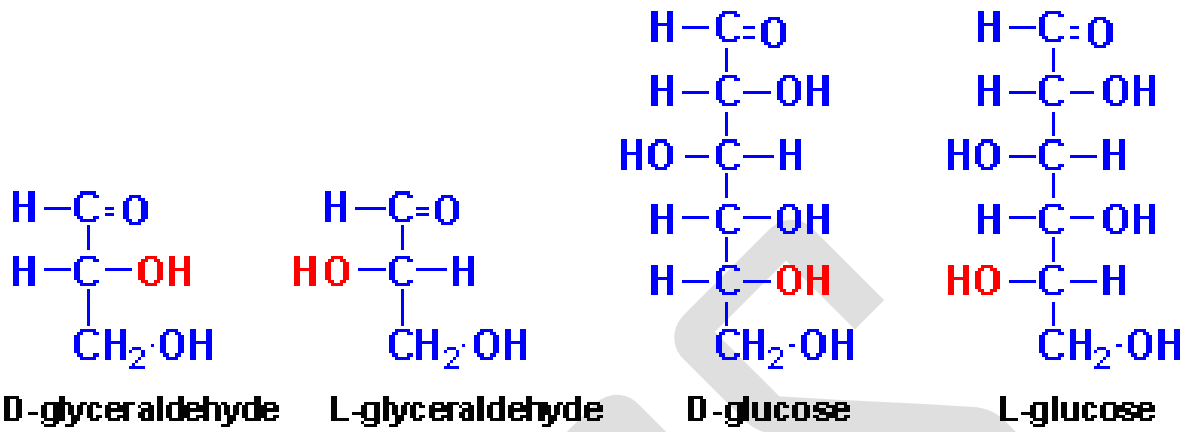


MONOSACCHARIDES:

- These are the simplest sugars, and can't be further hydrolyzed.
- **Stereo isomerism** is an important character of monosaccharides. Stereo isomers are the compounds having the same structural formula but differ in special configuration.
- A carbon with four different groups or atoms is known as **Asymmetric carbon**. The number of asymmetric carbons determines the number of possible isomers of a given compound which is equal to 2^n.

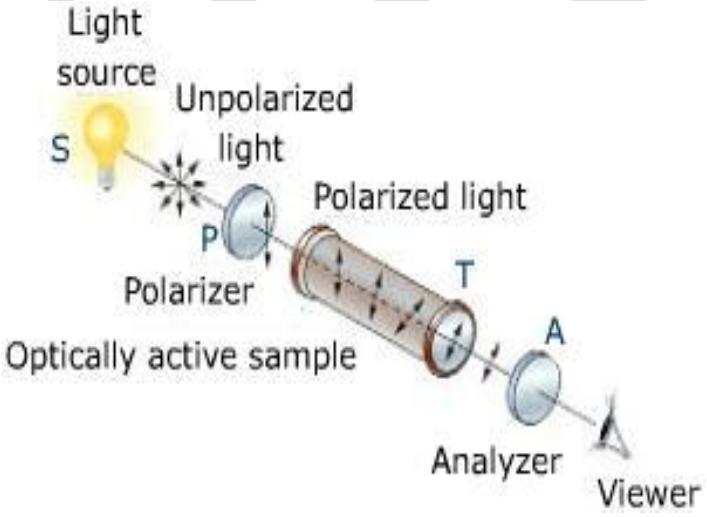
  Glucose – 4 asymmetric carbons.
  No of possible isomers of glucose = $2^n = 2^4 = 16$.

D- and L- Isomers: The D and L isomers are mirror images to each other. The spacial orientation of H- and OH- groups on the carbon atom (C_5) adjacent to the terminal primary alcohol carbon (C_6) determines D and L series.



When the OH- group on the carbon atom (C_5) is on the right side, the sugar is the D-isomer; when it is on the left, it is the L-isomer.

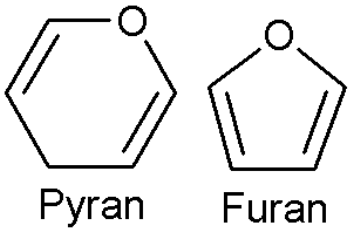
Optical Isomers: The presence of asymmetric carbon confers the optical activity on the compound. When a beam of plane polarized light is passed through a solution of optical isomer (sugar), it will be rotated either to the right, **Dextrorotatory (+)**; or on to the left, Levorotatory (-).

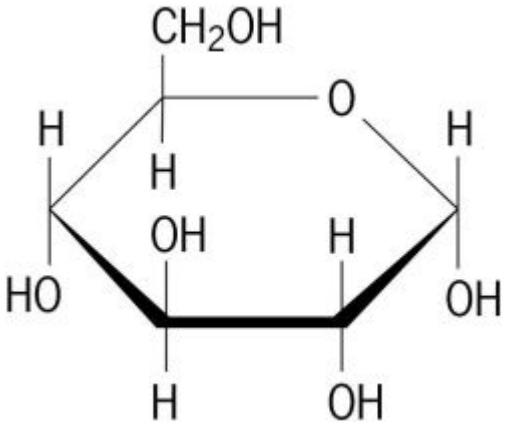


Optical activity is independent of the stereochemistry of the sugar, so it may be designated D(+), D(-), L(+), or ,L(-).

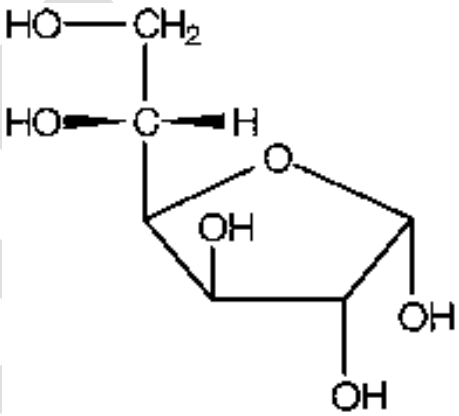
Pyranose and furanose ring structures:

The stable ring structures of monosaccharides are similar to ring structures of either pyran (six membered rinfgg).or furan (five membered ring).





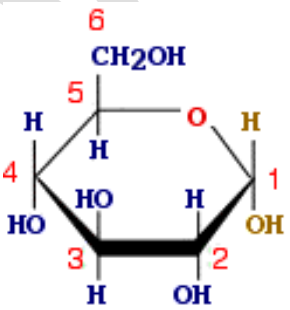
Glucopyranose



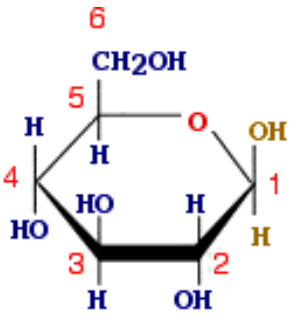
Glucofuranose

More than 99% of glucose solution is in pyranose form.

α and β anomers: The ring structure of glucose is in hemiacetal form, because it is formed by the combination of aldehyde and an alcohol. The spacial orientation of H- and OH- groups on the carbon atom (C_1) i.e carbonyl carbon or anomeric carbon determines α and β anomers.



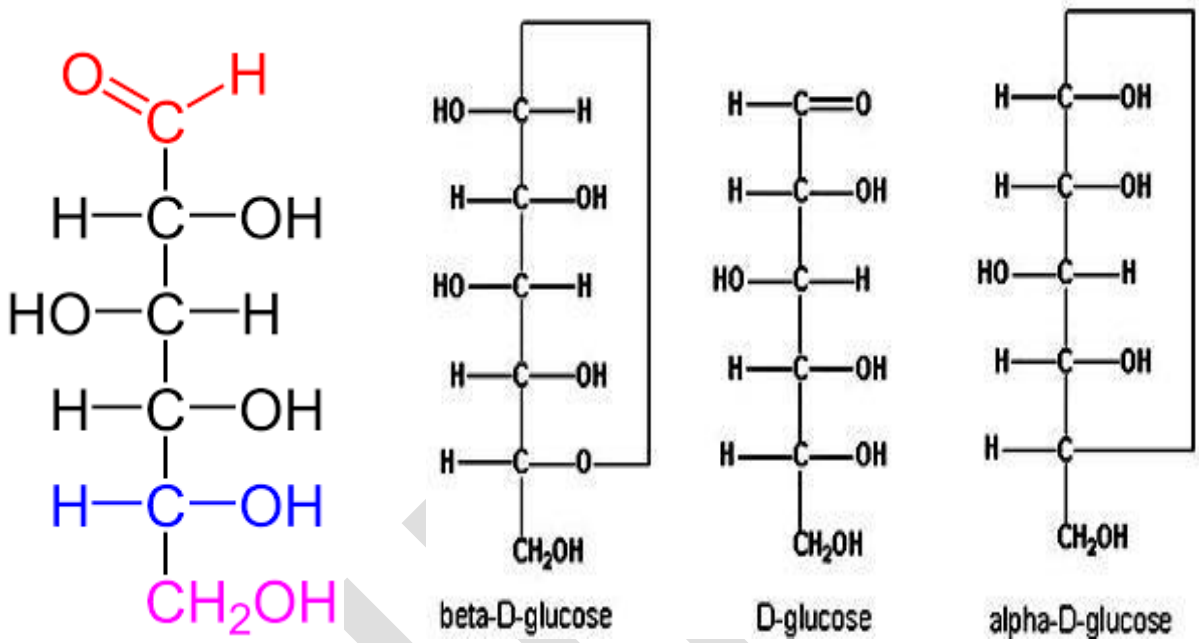
α-D-glucopyranose
(α-D-glucose)

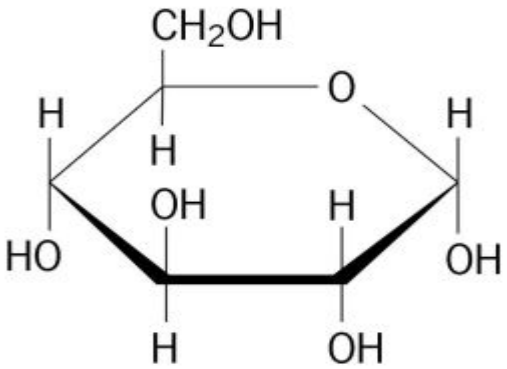


β-D-glucopyranose
(β-D-glucose)

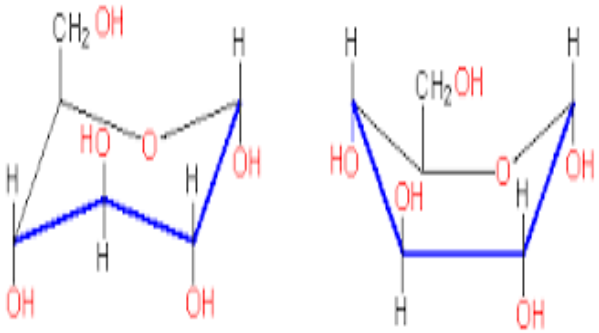
Epimers: Isomers differing as a result of variations in configuration of the OH- and H- groups on carbon atoms 2,3, and 4 of glucose are known as epimers.

Structure of Glucose:





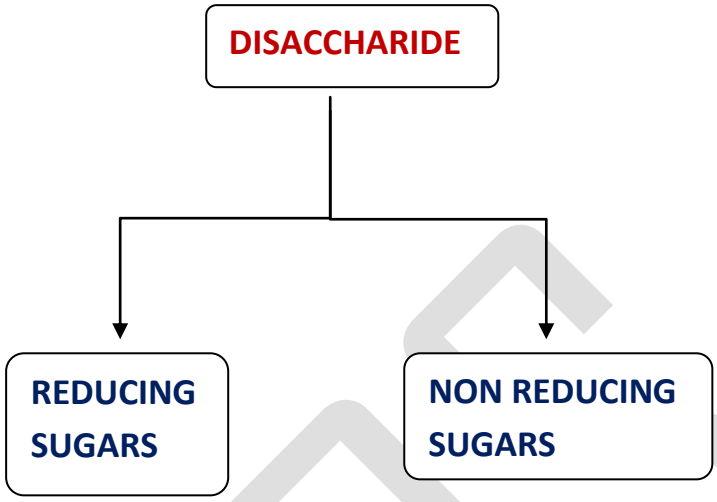
α- D-Glucose Haworth projection



α- D-Glucose chair form

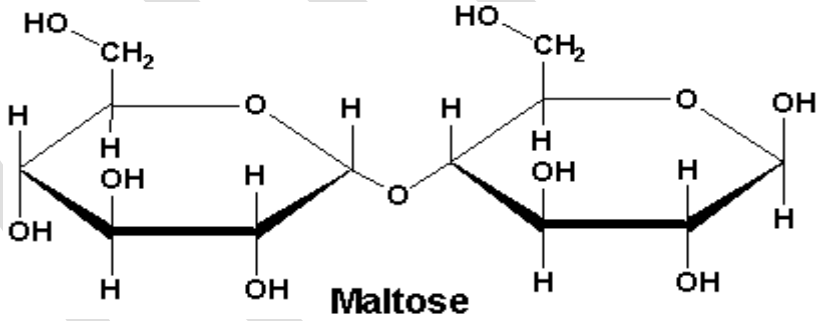
DISACCHARIDES:

A disaccharide consists of two monosaccharide units (similar or dissimilar) held together by a **glycosidic bond**.



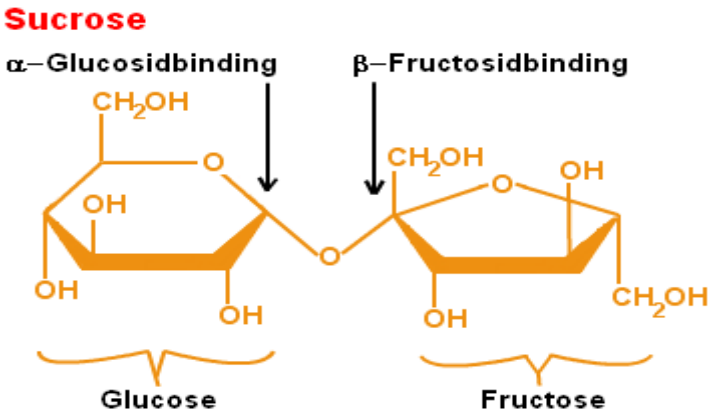
Reducing sugars: Disaccharides with free aldehyde or keto group.

Ex: Maltose, Lactose….



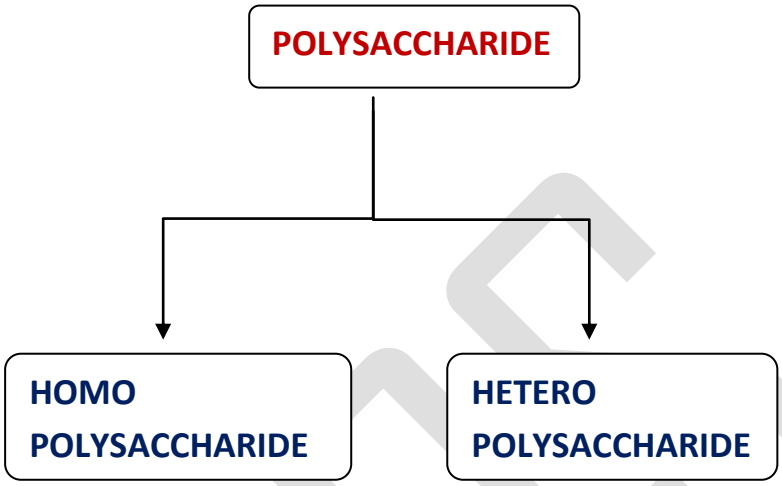
Non Reducing sugars: Disaccharides with no free aldehyde or keto group.

Ex: sucrose, trehalose….



POLYSACCHARIDES:

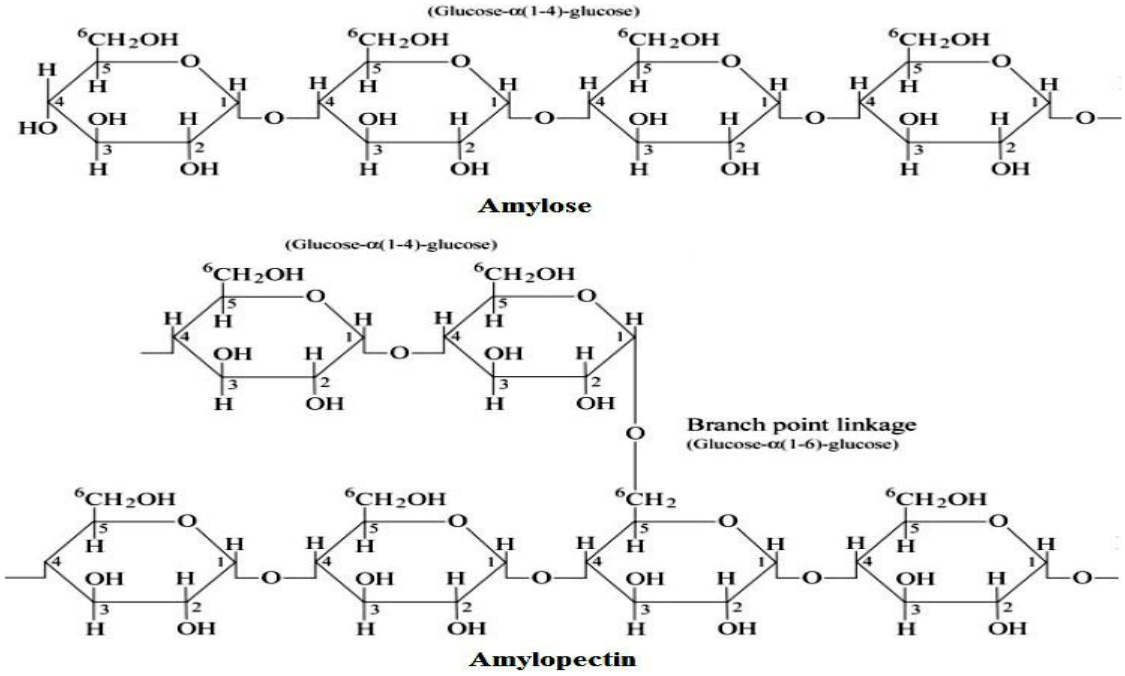
A polysaccharide consists of repeat monosaccharide units (similar or dissimilar) or their derivatives held together by a **glycosidic bond**. These are mainly concerned with storage of energy.



Homopolysaccharides: These contain only one type of monosaccharide, which on hydrolysis yield only a single type of monosaccharide.

Ex: Starch, inulin, Cellulose, glycogen….

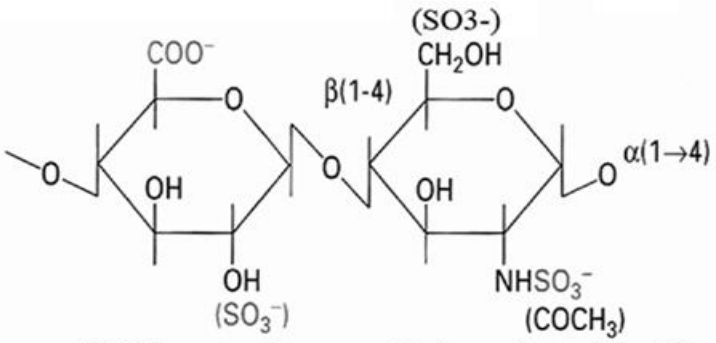
Starch consists of two polysaccharide components, water soluble **amylose** (15-20%) and water insoluble **amylopectin** (80-85%).



Heteropolysaccharides: These contain different types of monosaccharides, which on hydrolysis yields a mixture of monosaccharide units.

Ex: heparin, chondroitin, keratin, dermatan, …

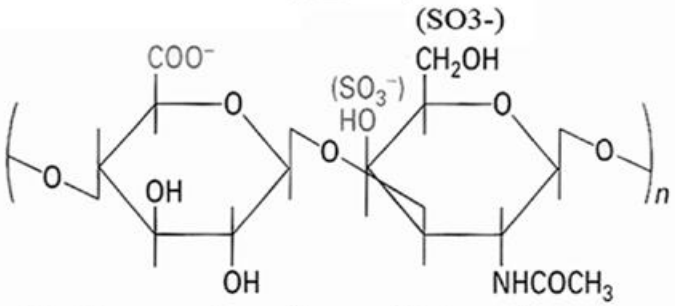
Heparin/heparan sulfate (n=15-30)



D-Glucuronic or L-iduronic acid

N-Acetyl- or N-sulfo-D-glucosamine

Chondroitin sulfate (n≤250)



D-Glucuronic acid

N-Acetyl-D-galactosamine

GLYCOPROTEINS: Several proteins are covalently bond to carbohydrates are referred to as Glycoproteins.

Protein + Carbohydrate = Glycoproteins

Ex: collagen,Immunoglobulins, Synovial glycoproteins, Intrinsic factor,….

References:

1. Biochemistry by U. Satyanarayana & U. Chakrapani.
2. Harper's Illustrated Biochemistry.
3. Text book of Biochemistry by Dr. A.V.S.S. Rama Rao.